National Aeronautics and Space Administration

Single Event Gate Rupture Characterization of the Fuji MOSFETs: 2SJ1A03 (A08P10), 2SJ1A09 (A08P20), and NSD1A01

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NASA Electronic Parts and Packaging (NEPP) Program
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1.0 PURPOSE

This testing is to characterize the power MOSFETs listed in Table 1.0-1 for single-event gate rupture (SEGR) and single-event burnout (SEB) response. Test results were compared against comparable voltage rated devices.

Table 1.0-1. List of power MOSFET devices that will be tested for SEE characterization.

Manufacturer	Part Number	Voltage rating (V)	Channel	Number provided	Package
FUJI	2SJ1A03 (11P10)	−100	P	50	TO-254
FUJI	2SJ1A09 (08P20)	−200	P	50	TO-254
FUJI	NSD1A01	600	N	50	24 DIP

2.0 TEST SAMPLES

The test samples are outlined in Table 1.0-1. Parts were handled in accordance with all ESD precautions. All parts had the following parameters measure before SEE testing: transconductance, voltage threshold, gate leakage. The following stress tests were applied to all devices: full off gate bias and 80% drain bias. All devices passed these tests and were approved for testing. Table 2.0-1 lists the steps required in preparing and vetting the parts in this test.

Table 2.0-1. List of power MOSFET devices that will be tested for SEE characterization.

Step	Part Numbers	Action	ATE	Serial Number and Calibration end date	Compliance
Check in	All	Verify part number, visually inspect for damage and assign SEE test serial number	NA	NA	Yes
Initial parametric test	All	Measure gm, Vth and Igss @ ±20 V	HP4156		Yes
Initial stress test	All	Apply absolute maximum Vgs (off) and absolute maximum Vds	HP4142		Yes
De-lid and die photo	All	De-lid and die photo	NA	NA	Yes

3.0 GENERAL

Eighteen (18) of the fifty (50) available NSD1A01 have been tested. Thirty six (36) of the fifty (50) available 2SJ1A09 have been tested. Twenty four (24) of the fifty (50) available 2SJ1A03 have been tested. Parts were tested at Brookhaven National Laboratory (BNL) and the Texas A&M University Radiation Effect Facility (TAMU-REF). See Table 3.0-1 for a list of tested parts and ions.

Table 3.0-1. Selected ion beam energy (15 MeV/amu).

Group	Qty	Part Number	Gate to Source Bias [V]	Site	Surface LET [MeV mg/cm^2]	Ion-Energy [MeV]	Ion (range in Si [μm])
A1	6	2SJ1A03	Vgs= 0, 5, 10, 15, 20	TAM	36	Kr-300	60
A2	6	2SJ1A03	Vgs= 0, 5, 10, 15	BNL	36.1	Br-279	37.45
A3	6	2SJ1A03	Vgs= 0, 5, 10, 15, 20	TAM	61	Xe-648	52.3
A4	6	2SJ1A03	Vgs= 0, 5, 10, 15, 20	TAM	27.1	Kr-1097	144.2
A5	6	2SJ1A03	Vgs= 0, 5, 10, 15, 20	TAM	50.2	Xe-1632	129
B1	6	2SJ1A09	Vgs= 0, 5, 10, 15	TAM	94.4	Au-1768	88.1
B2	6	2SJ1A09	Vgs= 0, 5, 10, 15	TAM	31.5	Xe-333	63.4
B3	6	2SJ1A09	Vgs= 0, 5, 10, 15	TAM	50.9	Xe-1569	124.5
B4	6	2SJ1A09	Vgs= 0, 5, 10, 15	TAM	36	Kr-300	60
B4	6	2SJ1A09	Vgs= 0, 5, 10, 15	BNL	36.1	Br-279	37.45
B5	6	2SJ1A09	Vgs= 0, 5, 10, 15	TAM	27.1	Kr-1097	144.2
C1	3	NSD1A01	Vgs= 0, –5	TAM	84.7	Au-2342	123
C2	3	NSD1A01	Vgs= 0, –5	TAM	94.4	Au-1768	88.1
C3	6	NSD1A01	Vgs= 0, –5, –10, –15	TAM	50.9	Xe-1569	124.5
C4	3	NSD1A01	Vgs= 0, –5, –10	TAM	34.8	Kr-533	64.6
C5	3	NSD1A01	Vgs= 0, –5, –10	TAM	31	Kr-733	96.1
C6	3	NSD1A01	Vgs= 0, –5, –10	TAM	50.2	Xe-1632	129

4.0 ELECTRICAL TESTS

Electrical tests were performed in accordance with "The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs" [JPL Publication 08-10 2/08]. The threshold voltage (Vth) and transconductance (gm) were measured on all parts prior to irradiation. All parts were in specification. However, the 2SJ1A03 (A08P10) exhibited forward breakdown when the full off-gate-to-source bias (Vgs-off) and full drain-to-source bias (Vds) were simultaneously applied to these devices. Figure 4.0-1 through Figure 4.0-38 present the effect. This phenomenon prevented the post irradiation test of simultaneous full gate and drain stress, which altered the failure criteria in section 5.0. However, this condition did not prevent the biasing conditions required for SEE testing.

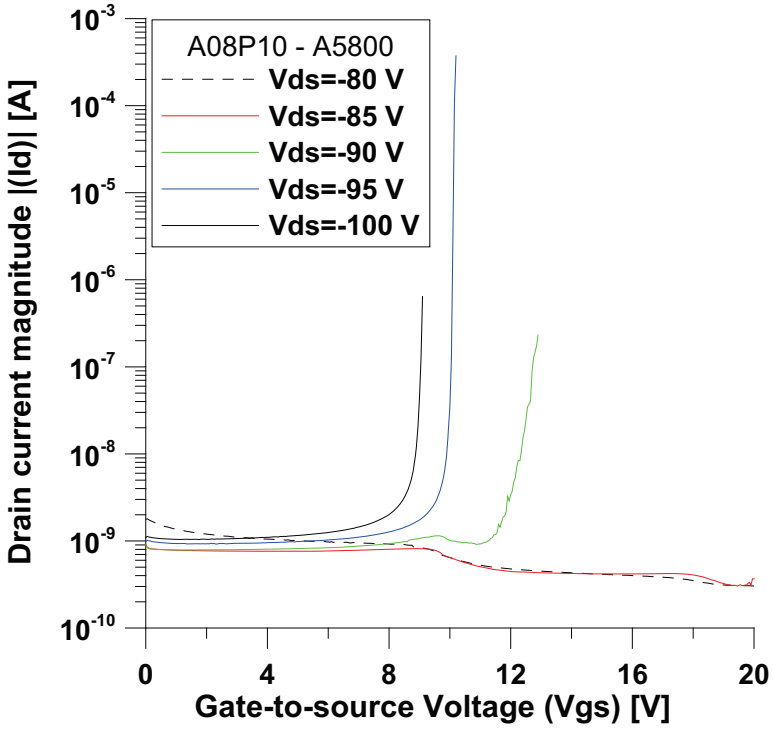
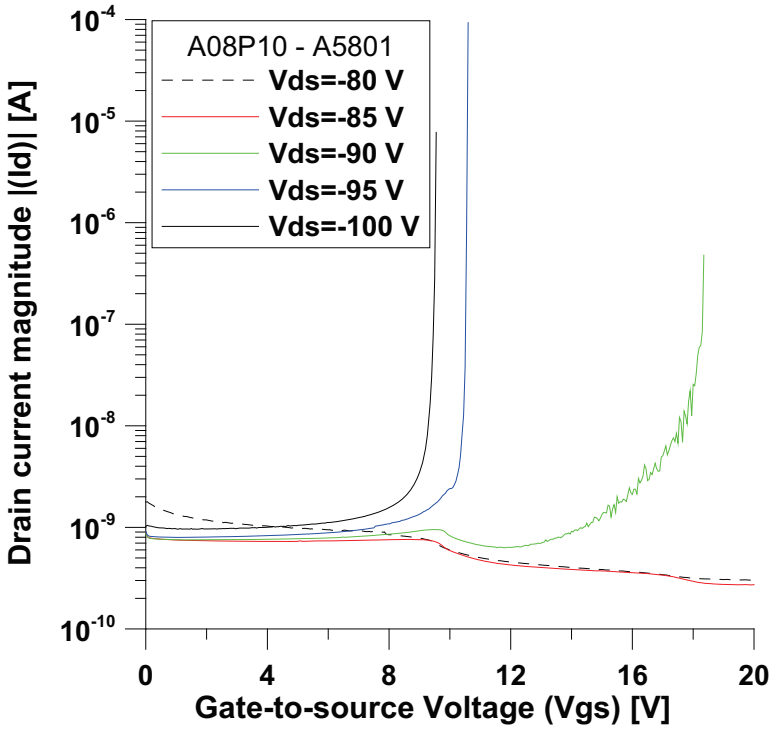


Figure 4.0-1



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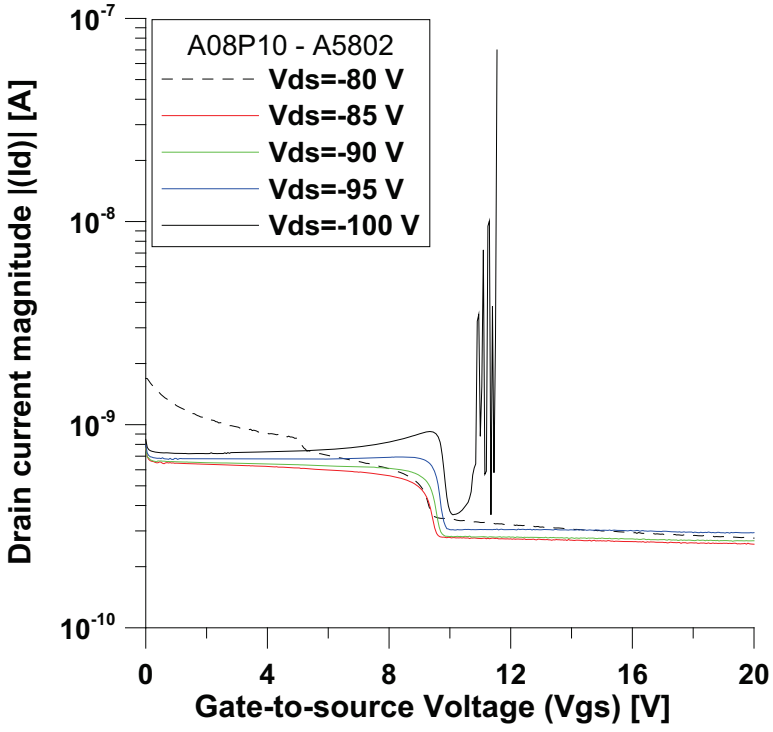

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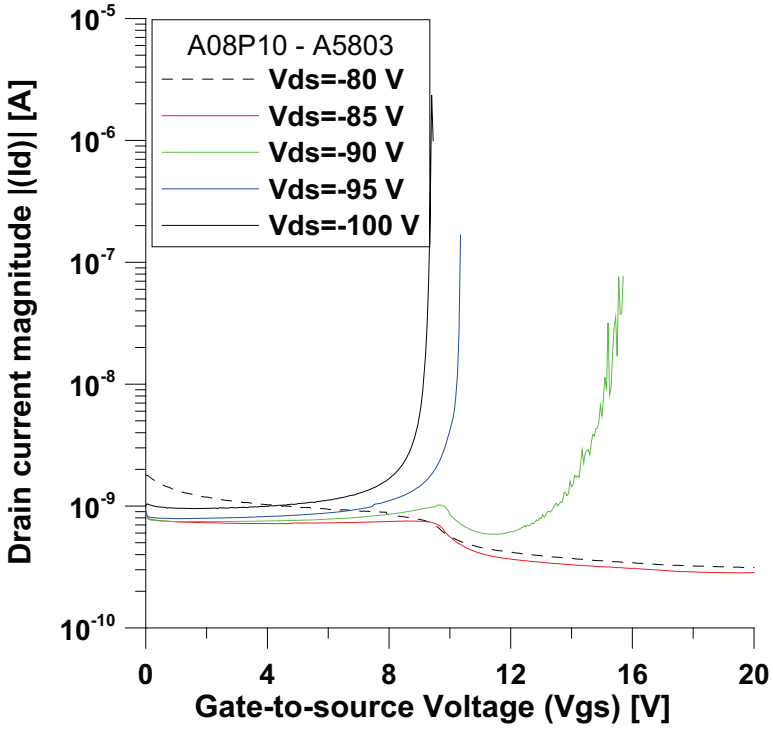

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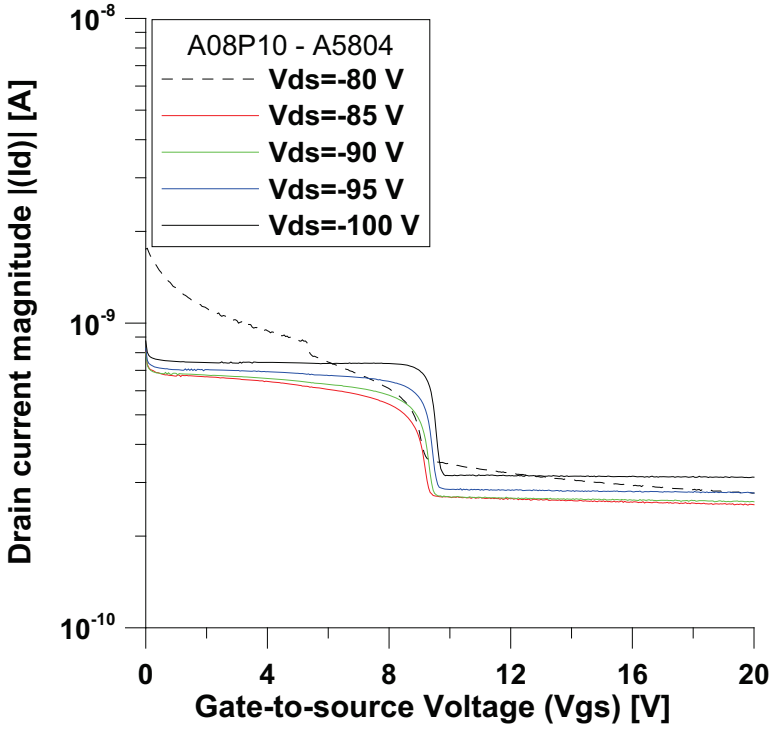

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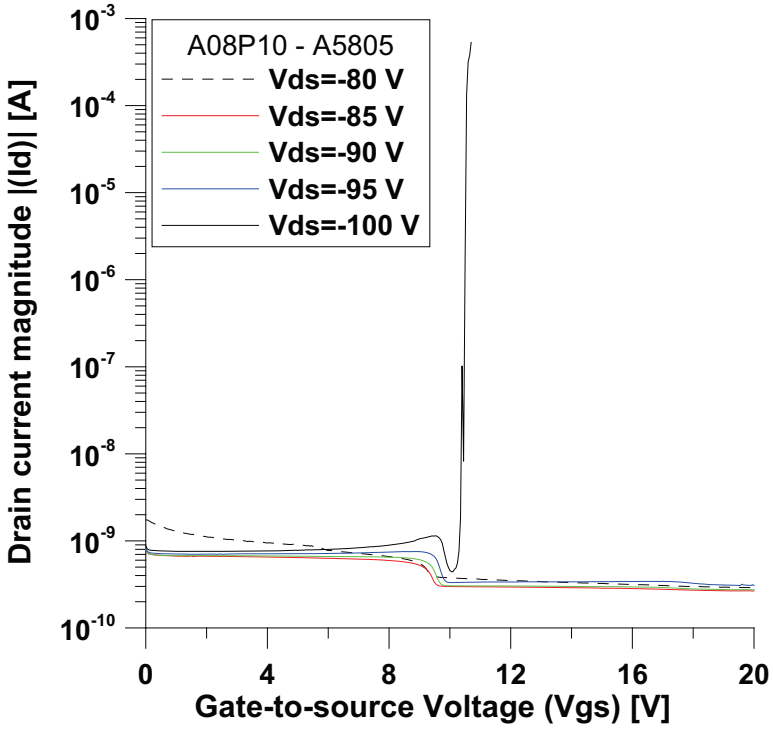

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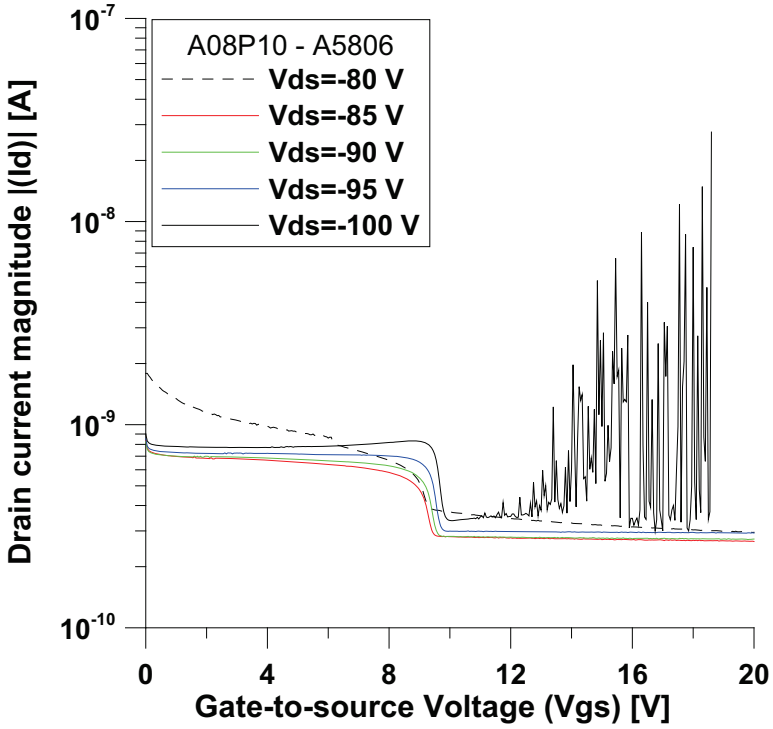

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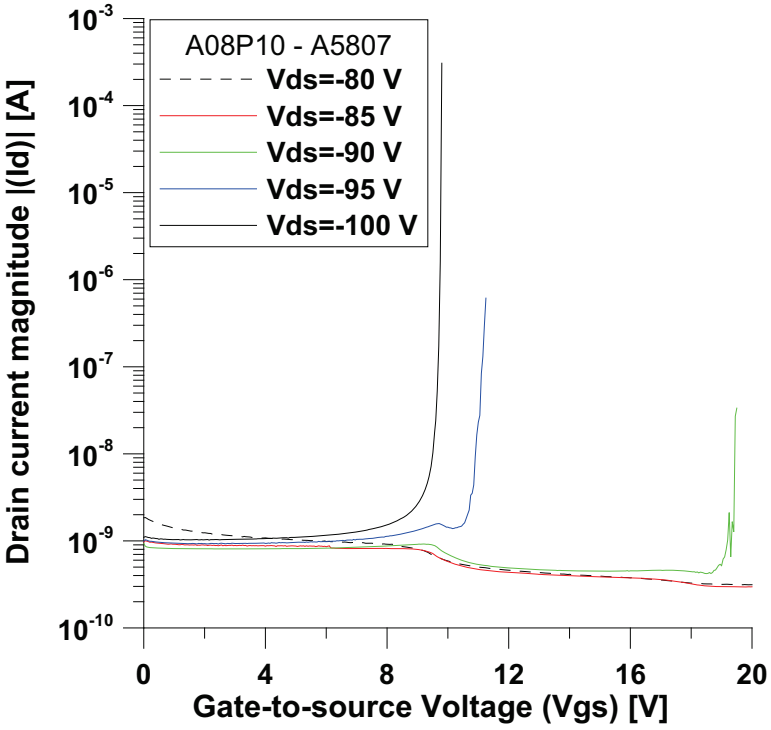

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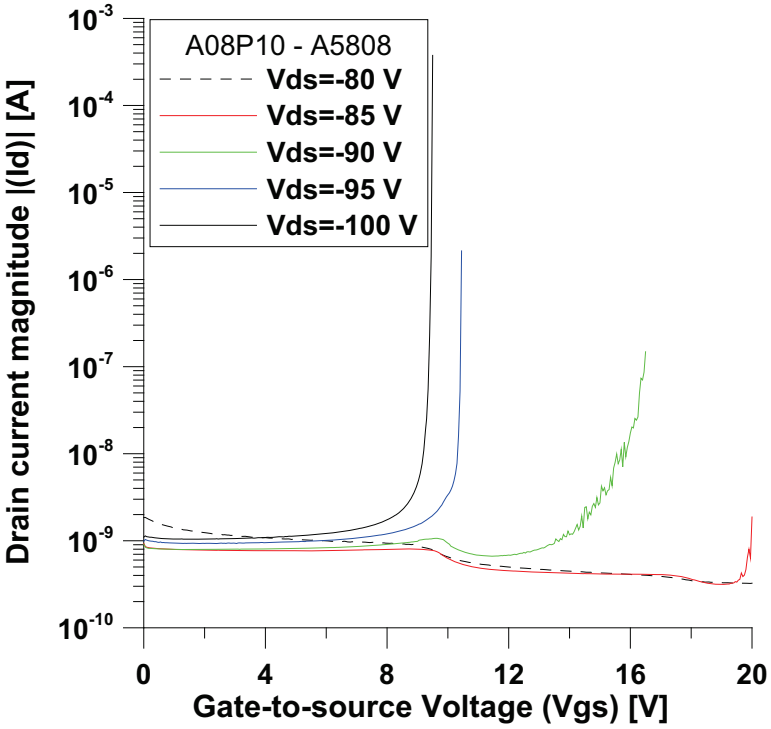

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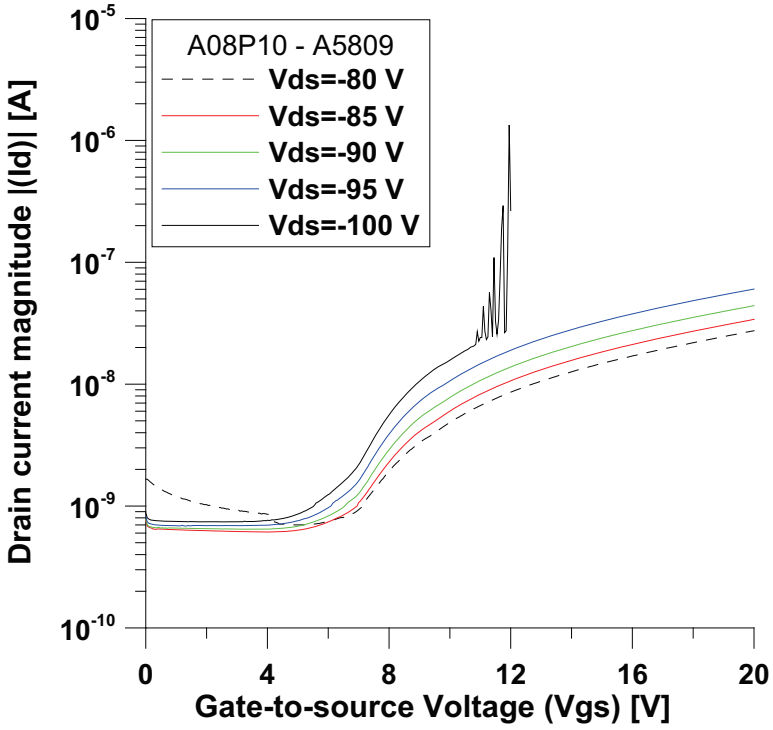

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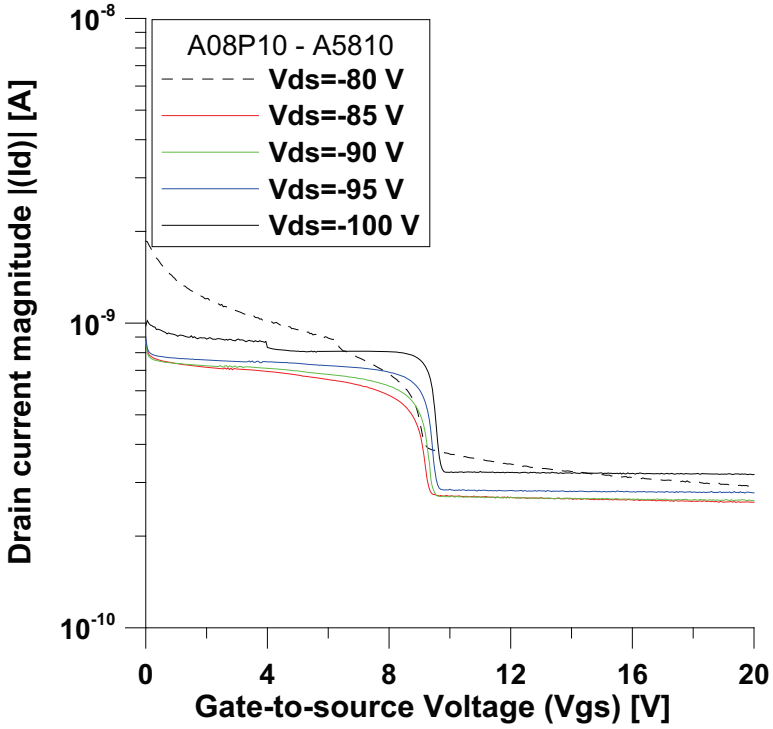

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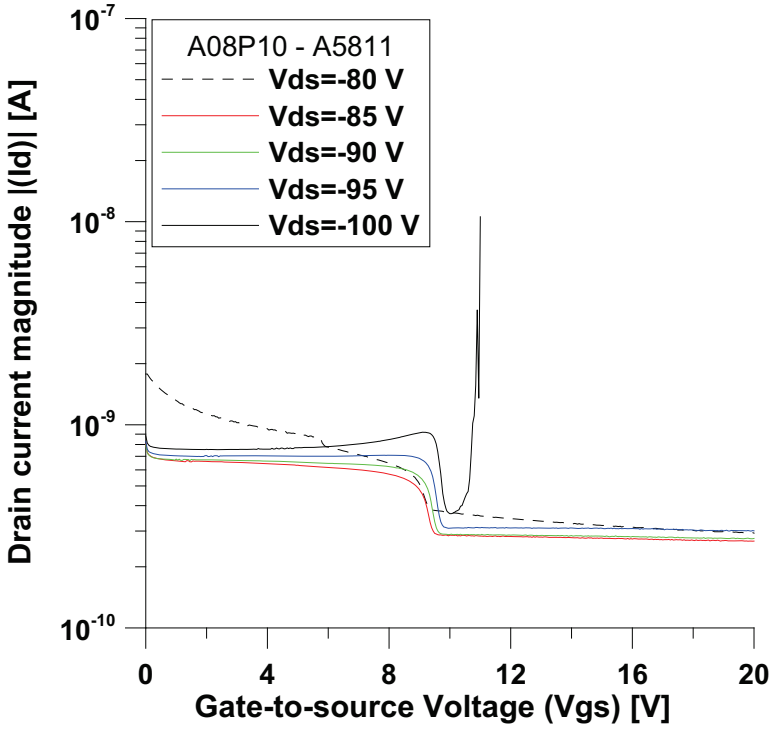

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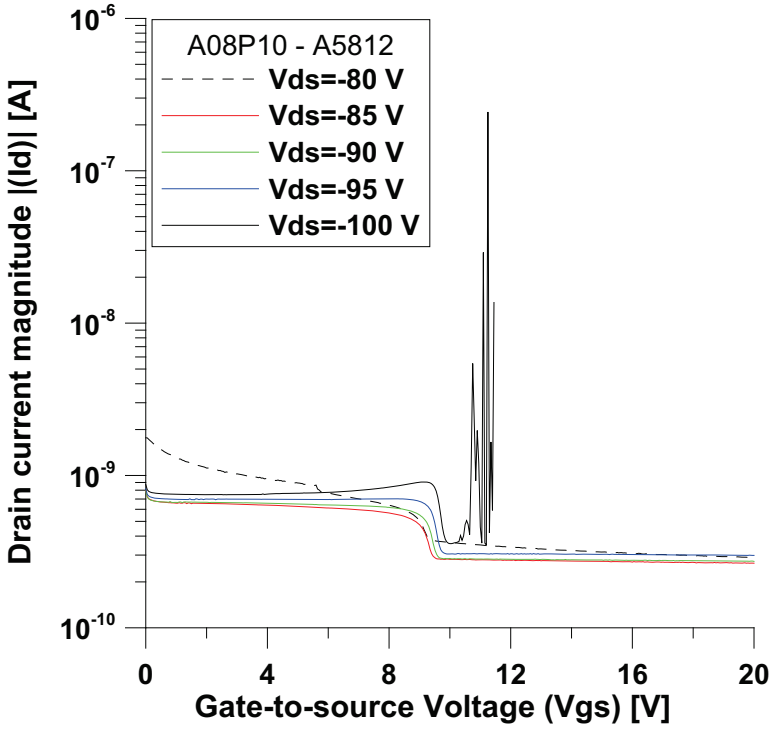

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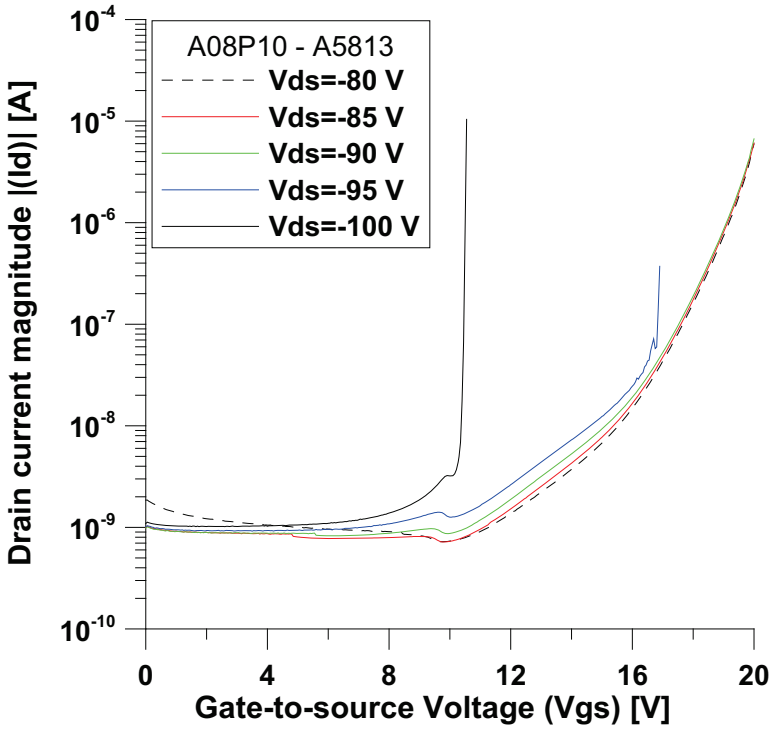

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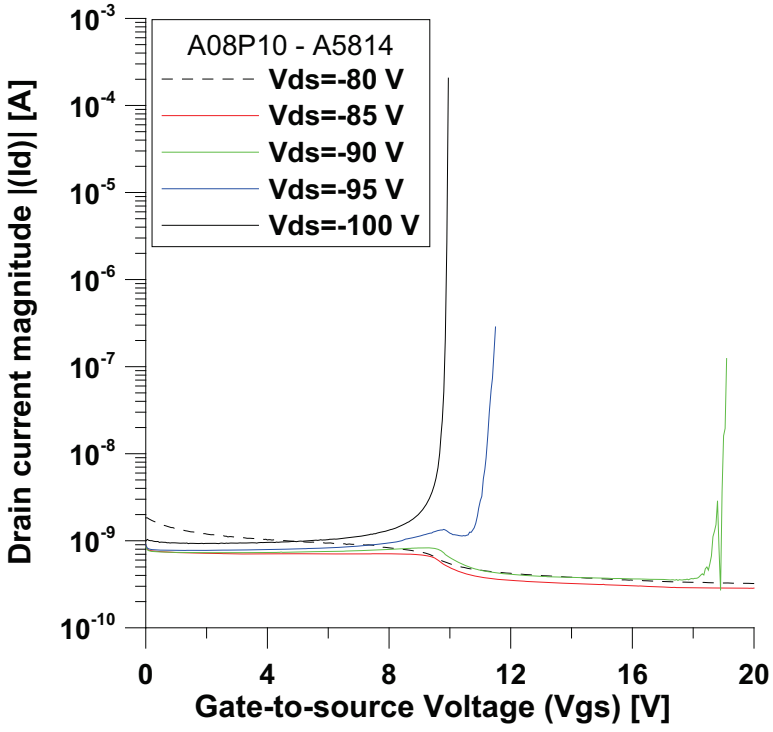

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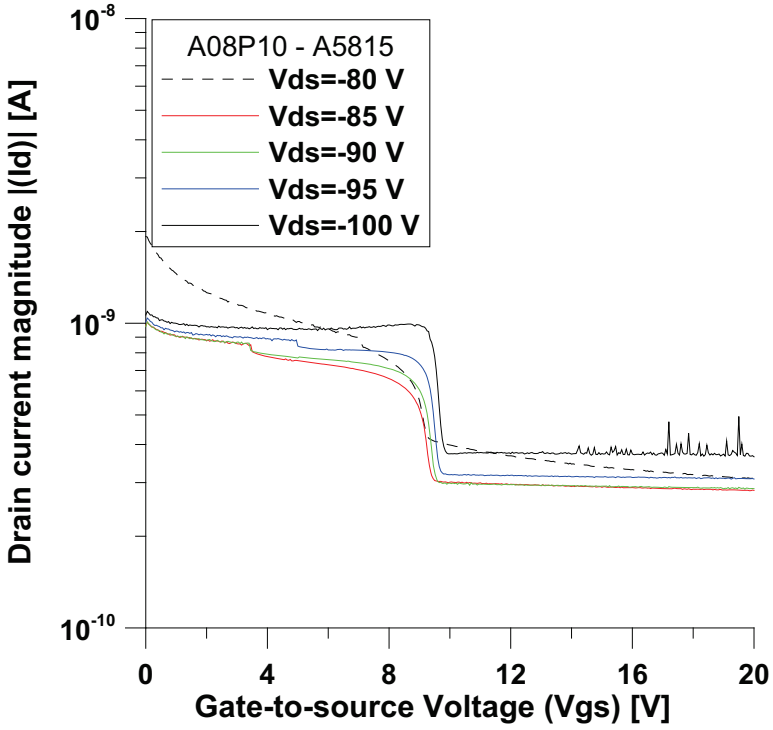

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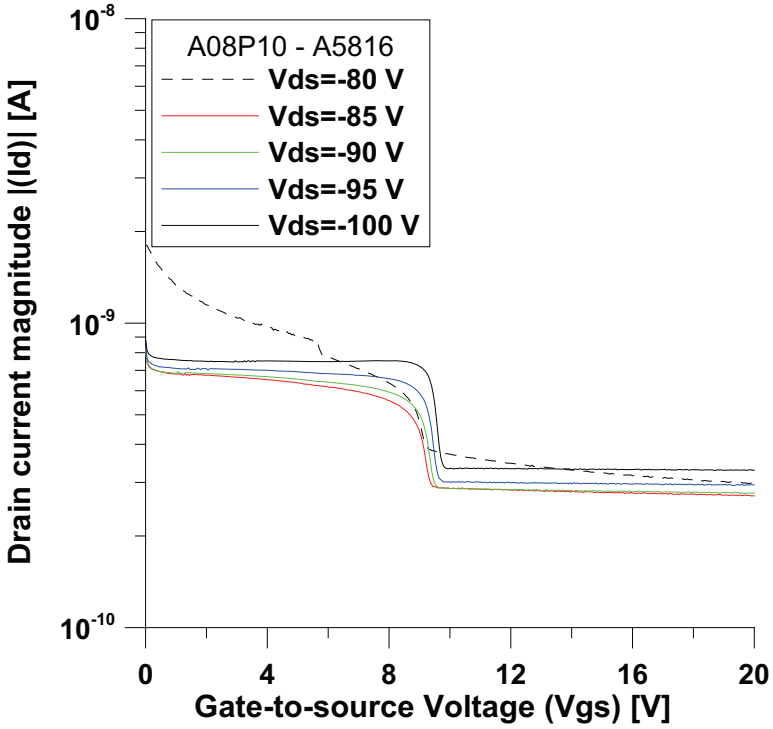

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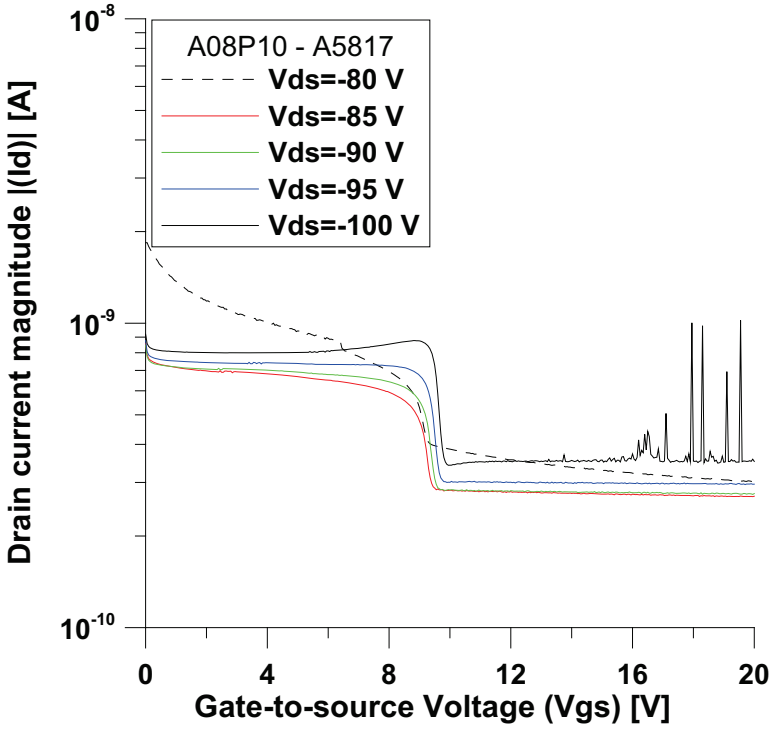

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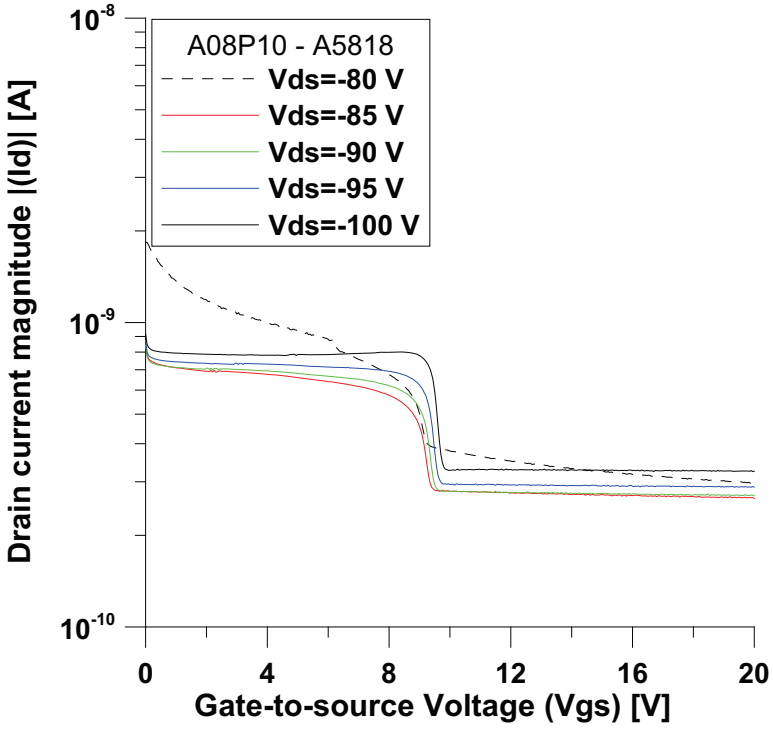

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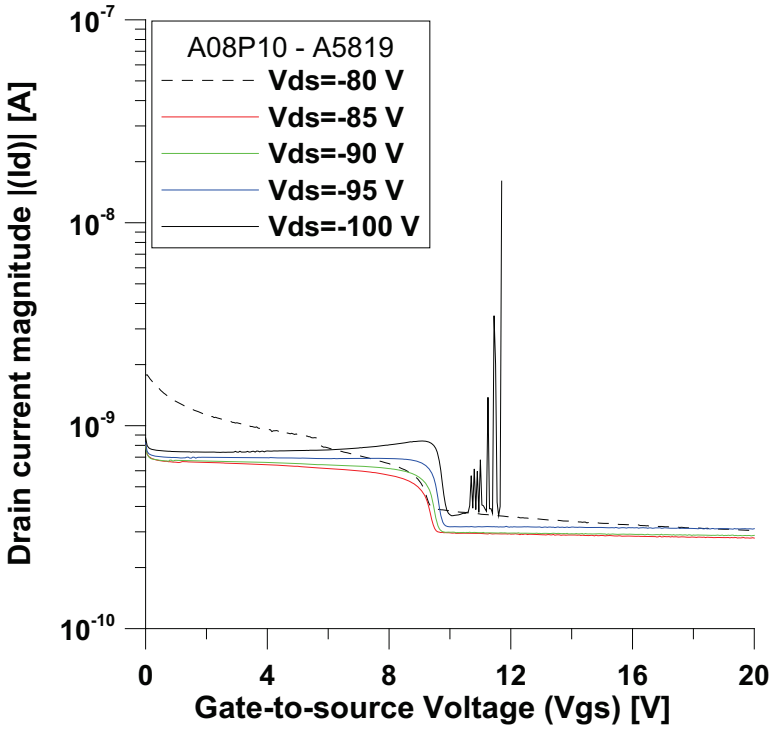

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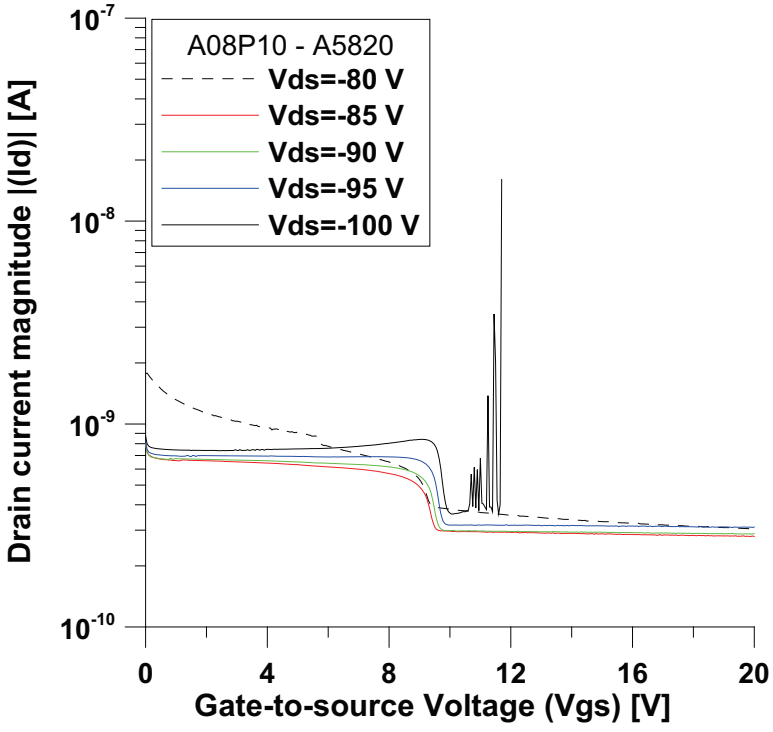

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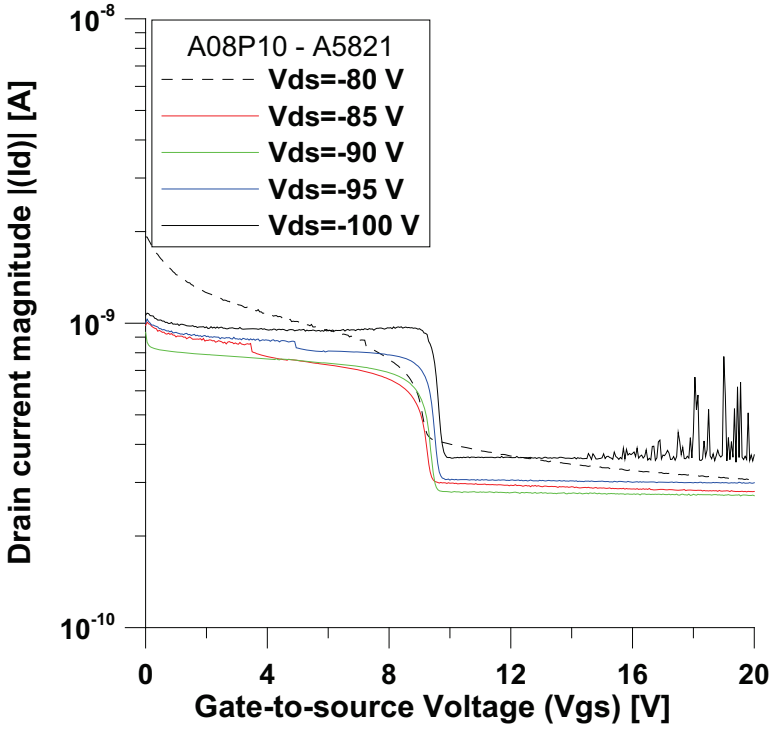

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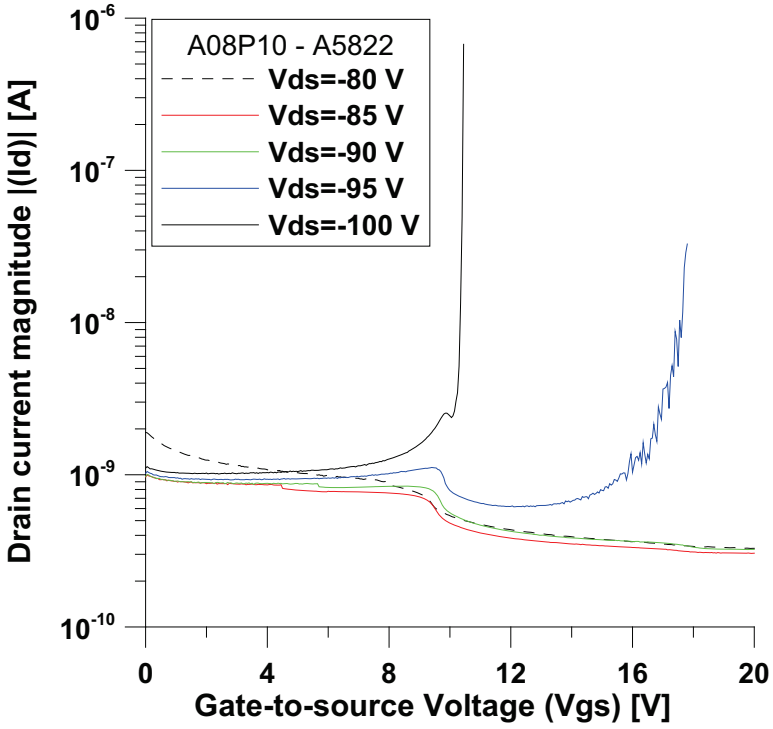

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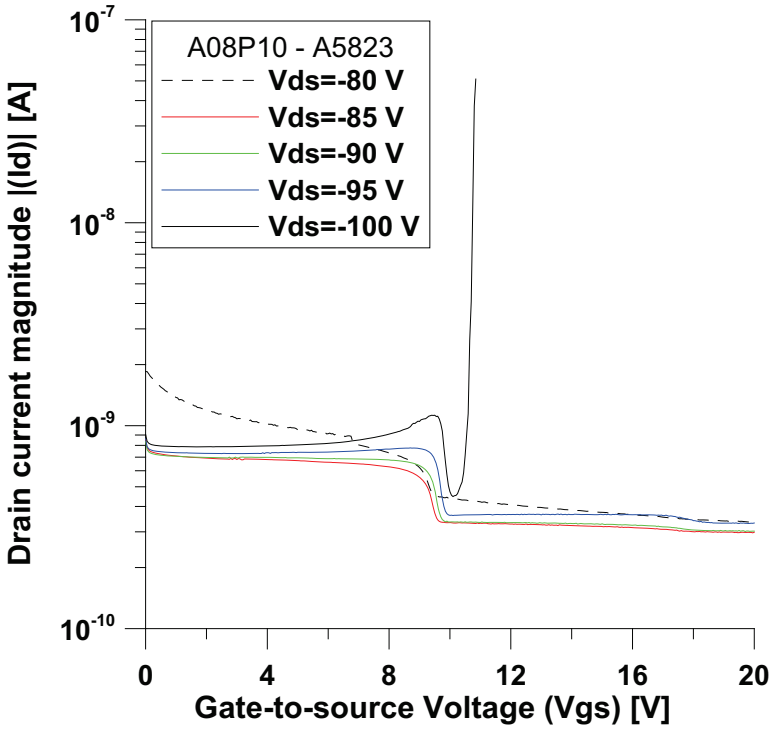

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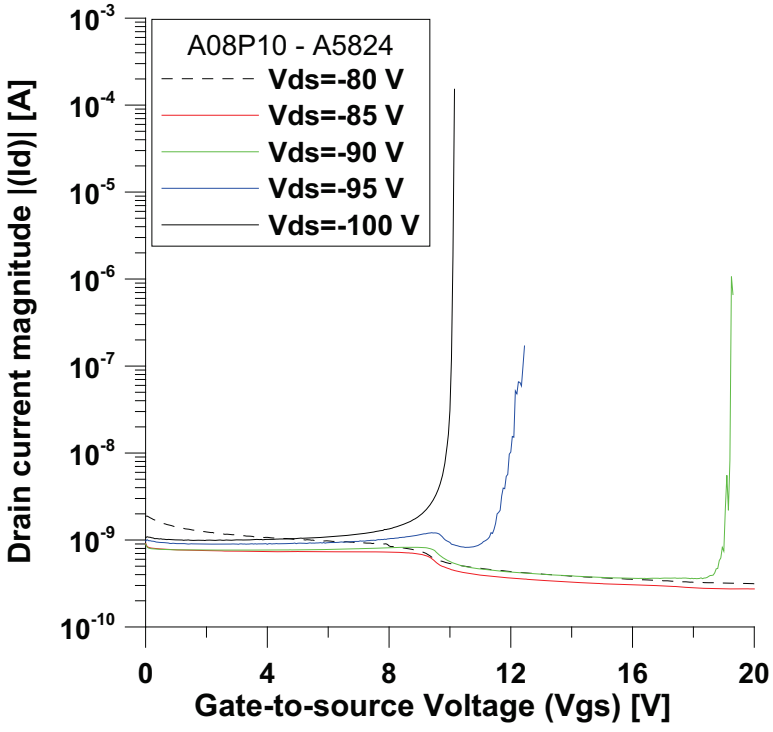

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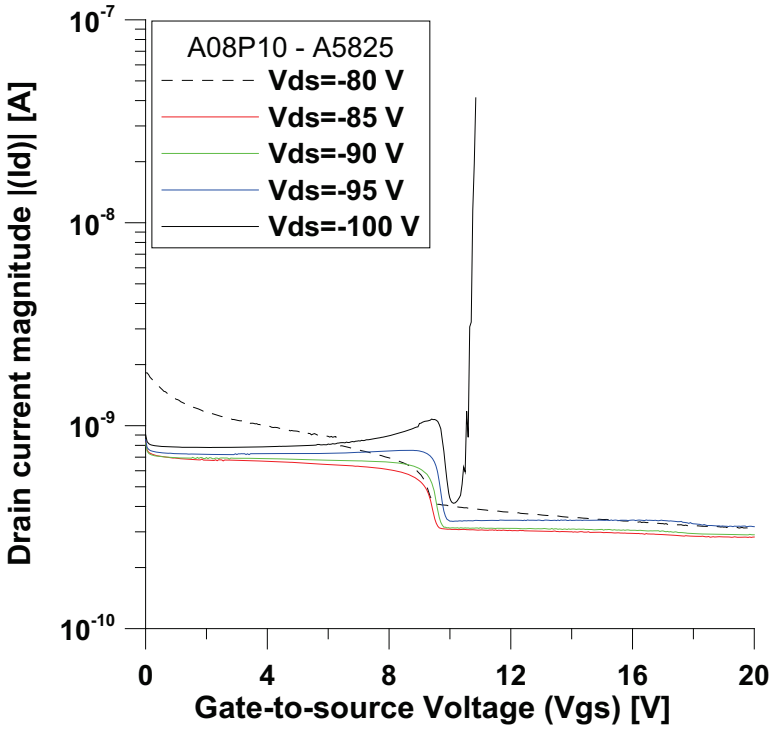

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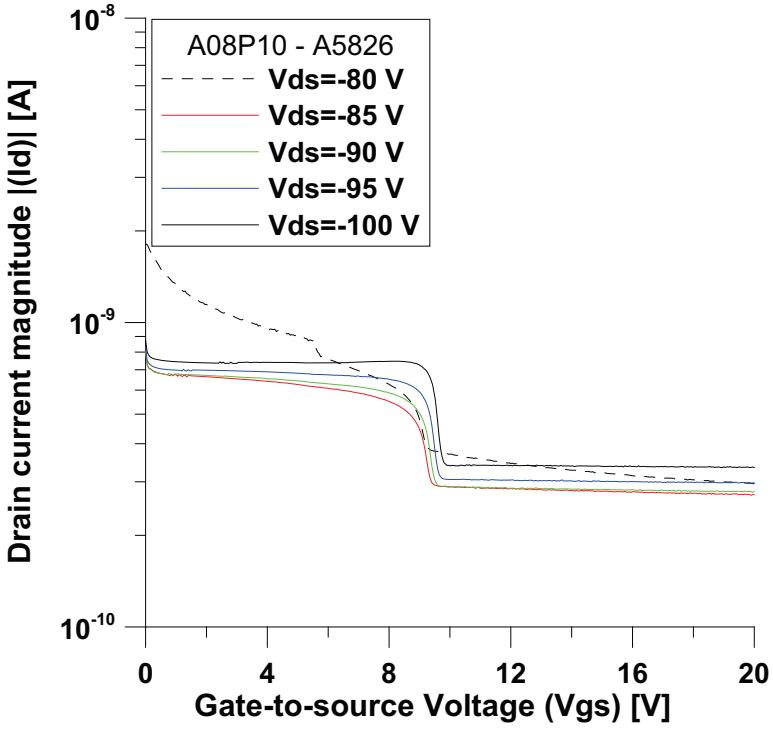

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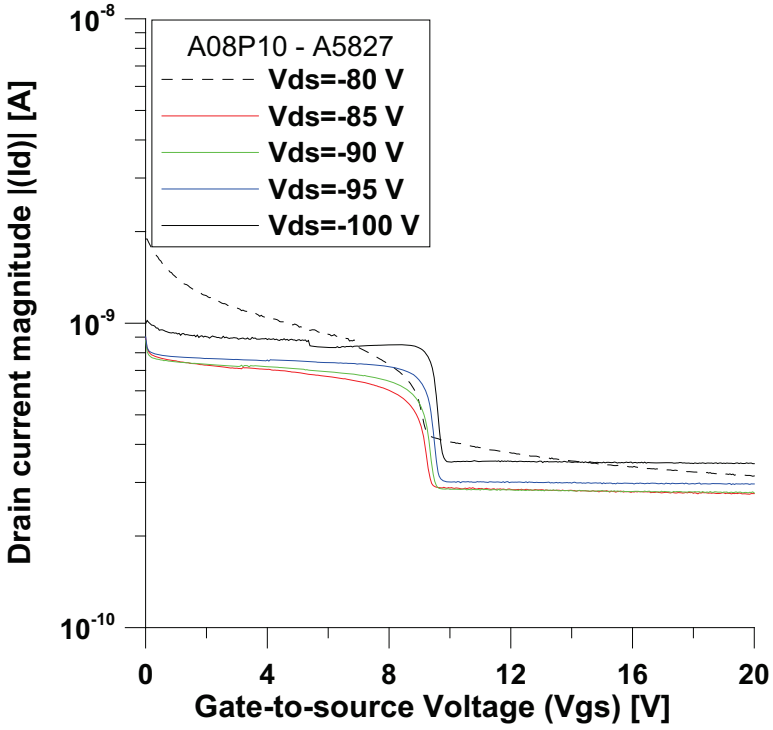

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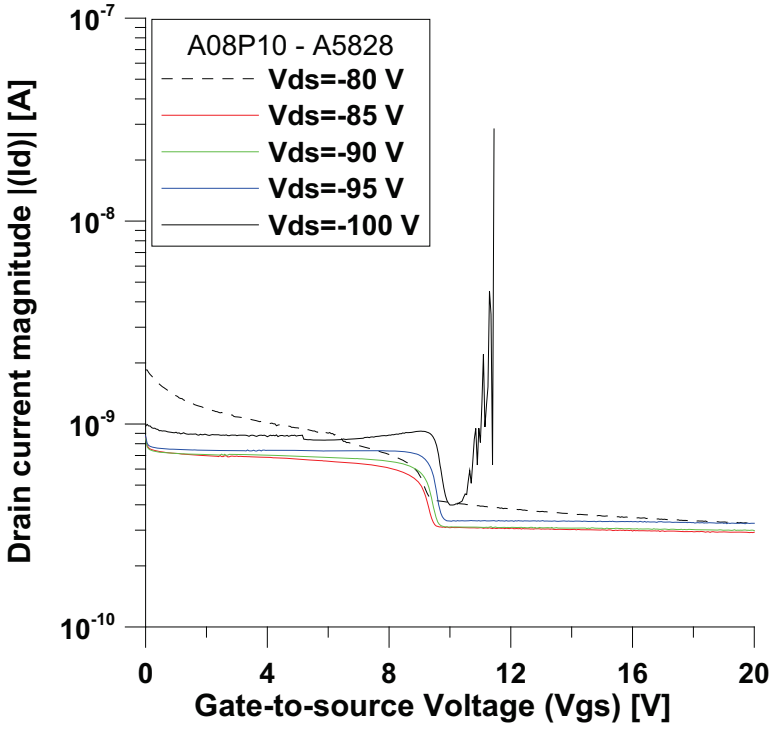

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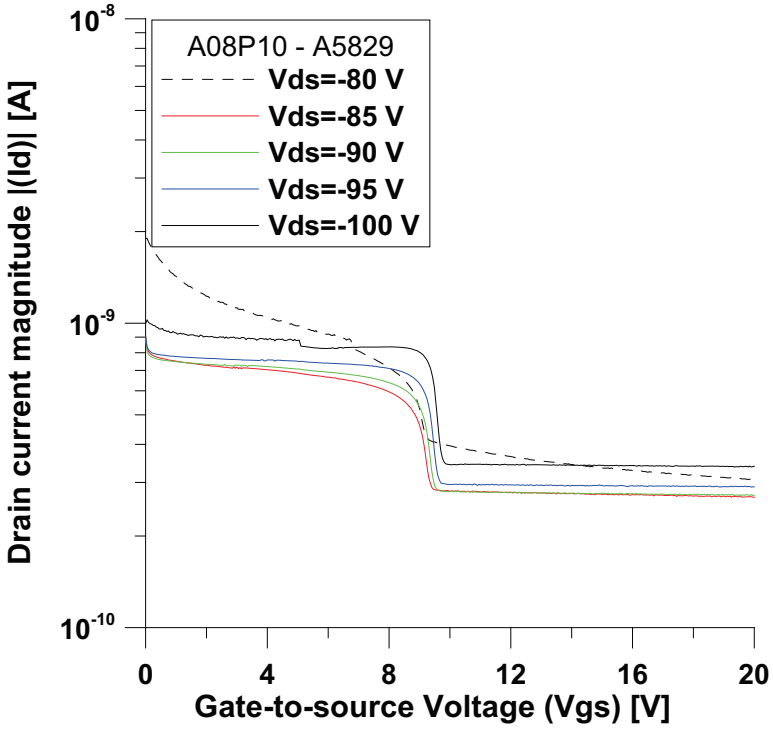

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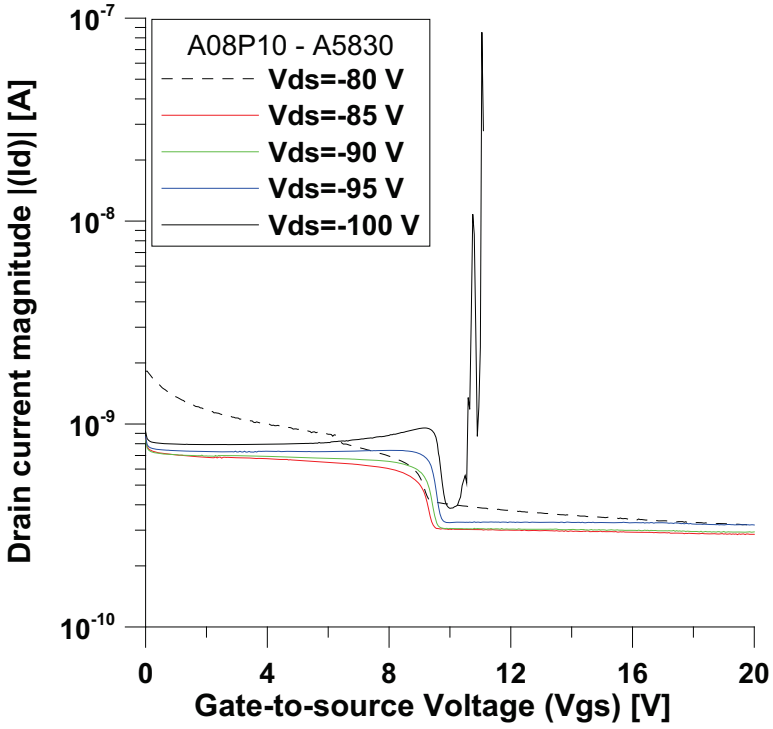

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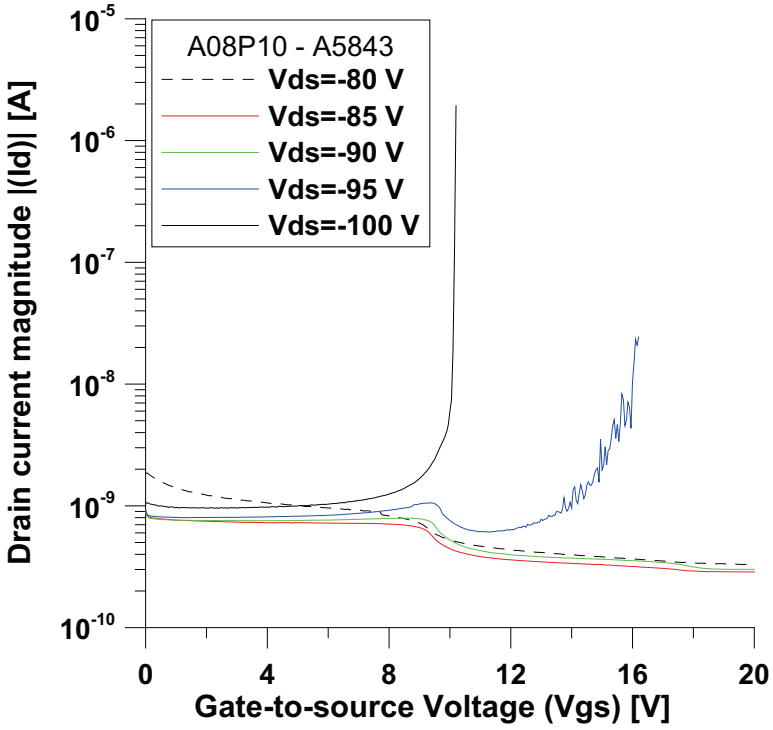

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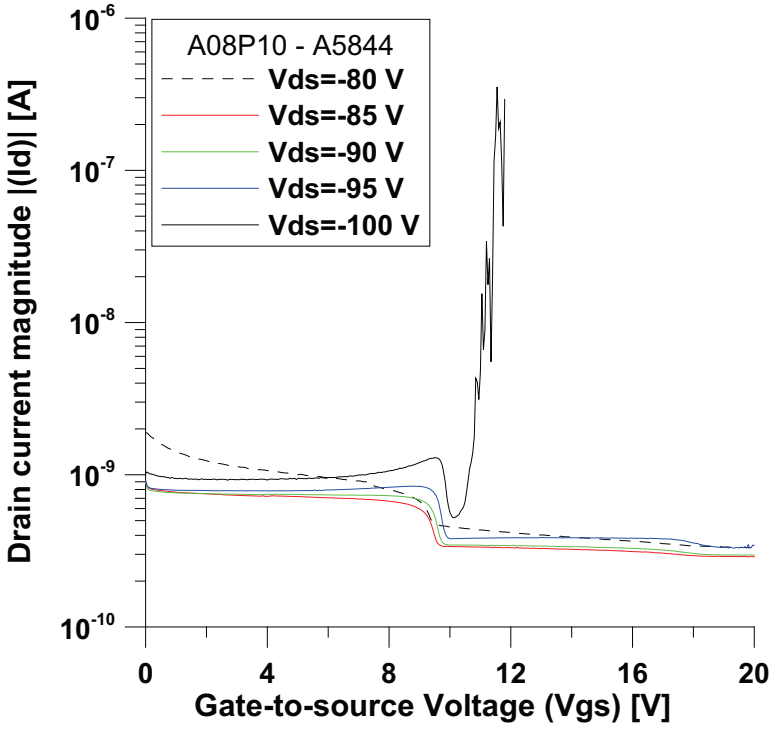

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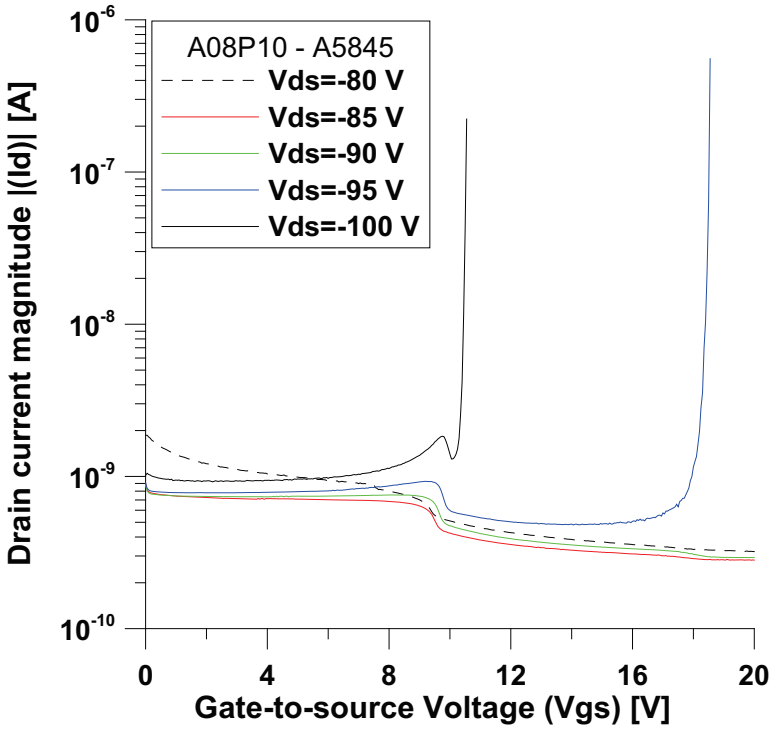

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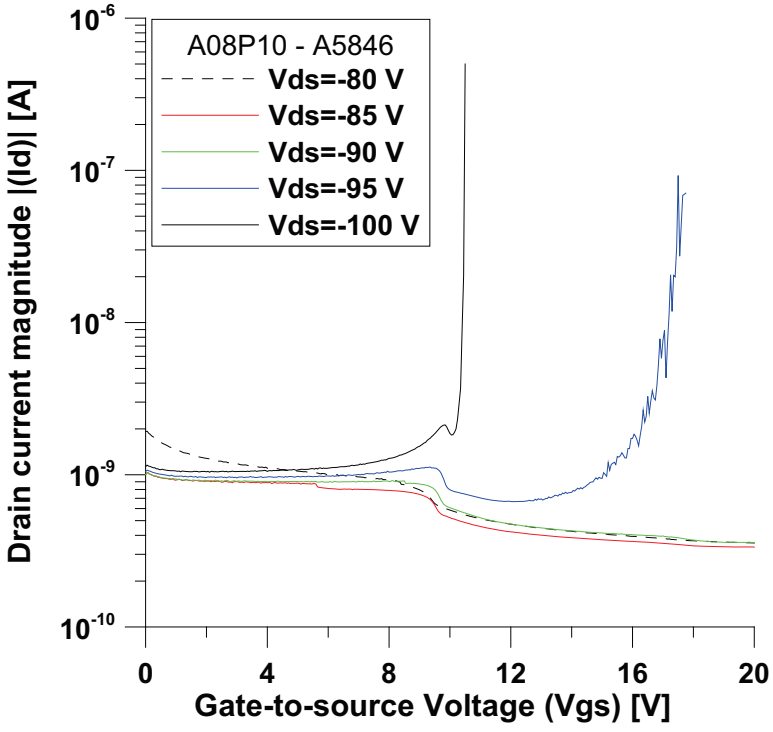

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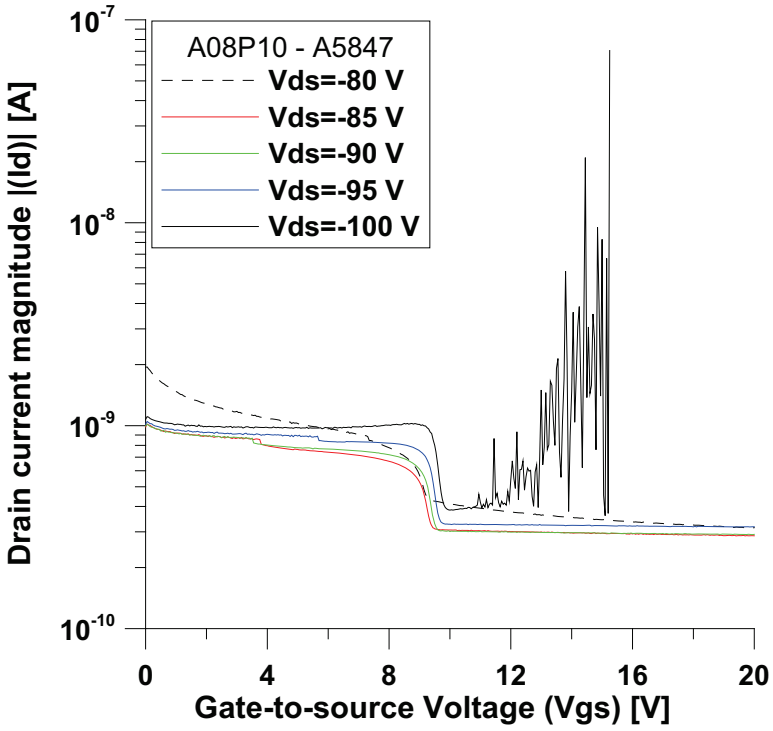

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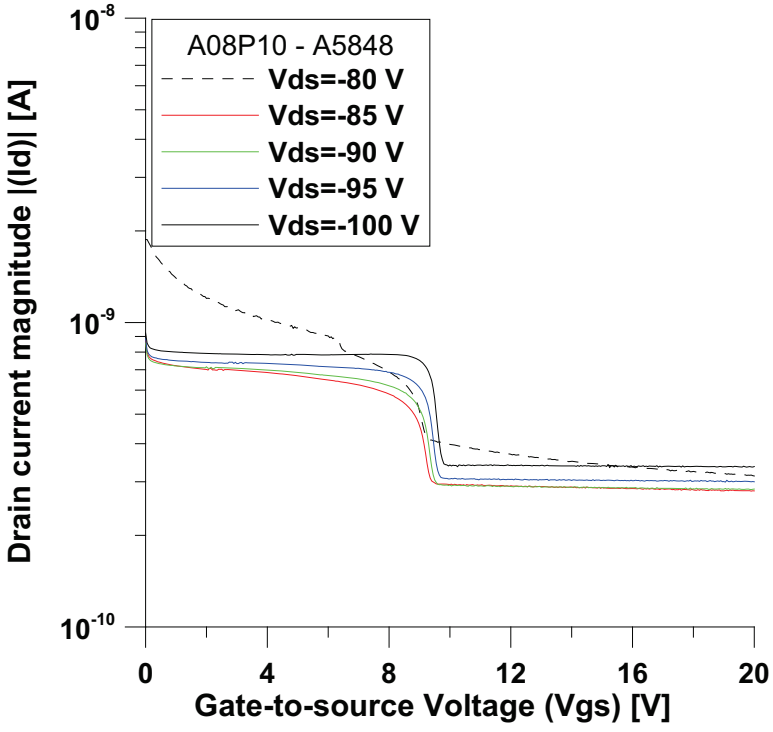

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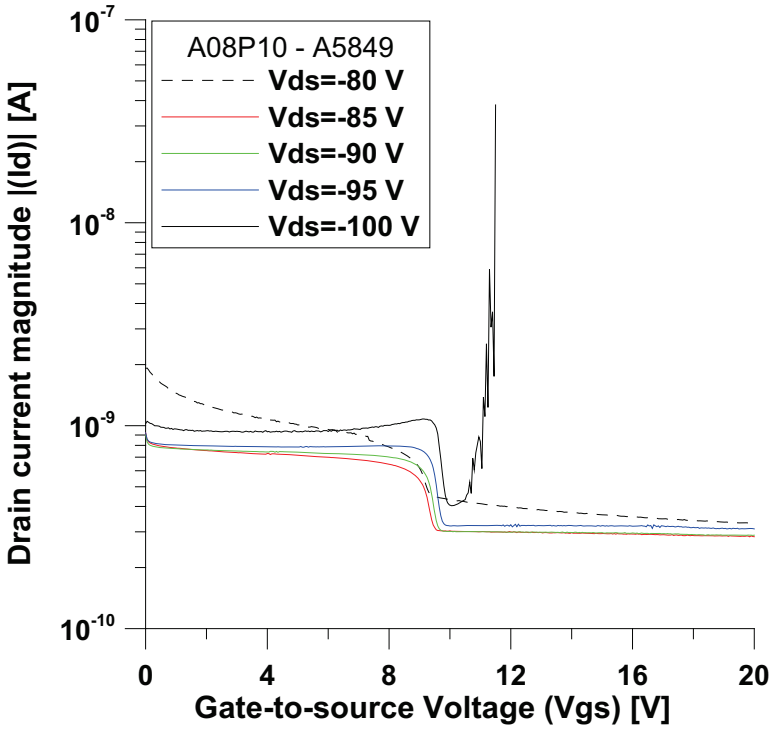
A08P10 - A5849
Vds=-80 V
Vds=-85 V
Vds=-90 V
Vds=-95 V
Vds=-100 V
Drain current magnitude |(Id)| [A]
10-7
10-8
10-9
10-10
0
4
8
12
16
20
Gate-to-source Voltage (Vgs) [V]

Figure 4.0-38

5.0 FAILURE CRITERIA

Failure criteria shall be classified in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [JPL Publication 08-10 2/08]. Due to the 2SJ1A03 (A08P10) not being able to support full off-gate and drain bias, the post irradiation stress test (PIST) was a gate stress of −20 V followed by an application 80% of drain bias for 3 seconds. Out of specification reading during irradiation or either stress test was considered an SEE caused failure.

6.0 SCHEDULE

These tests occurred on February 22, 2012 at BNL and March.23, 2012 at TAM.

7.0 BIAS CONDITION/FIXTURES

Bias condition during the biased irradiations shall be in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [JPL Publication 08-10 2/08]. Unbiased parts shall be exposed in a manner that protects them against ESD.

7.1 Setup

Failure criteria were classified in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [JPL Publication 08-10 2/08]. Figure 7.1-1 shows the setup used in this experiment. An HP4142 forced the voltage and read a current with three independent SMUs. The background current on the board with no DUT was recorded to be ~0.5 nA in each device location. All parts were tested at ambient laboratory temperatures.

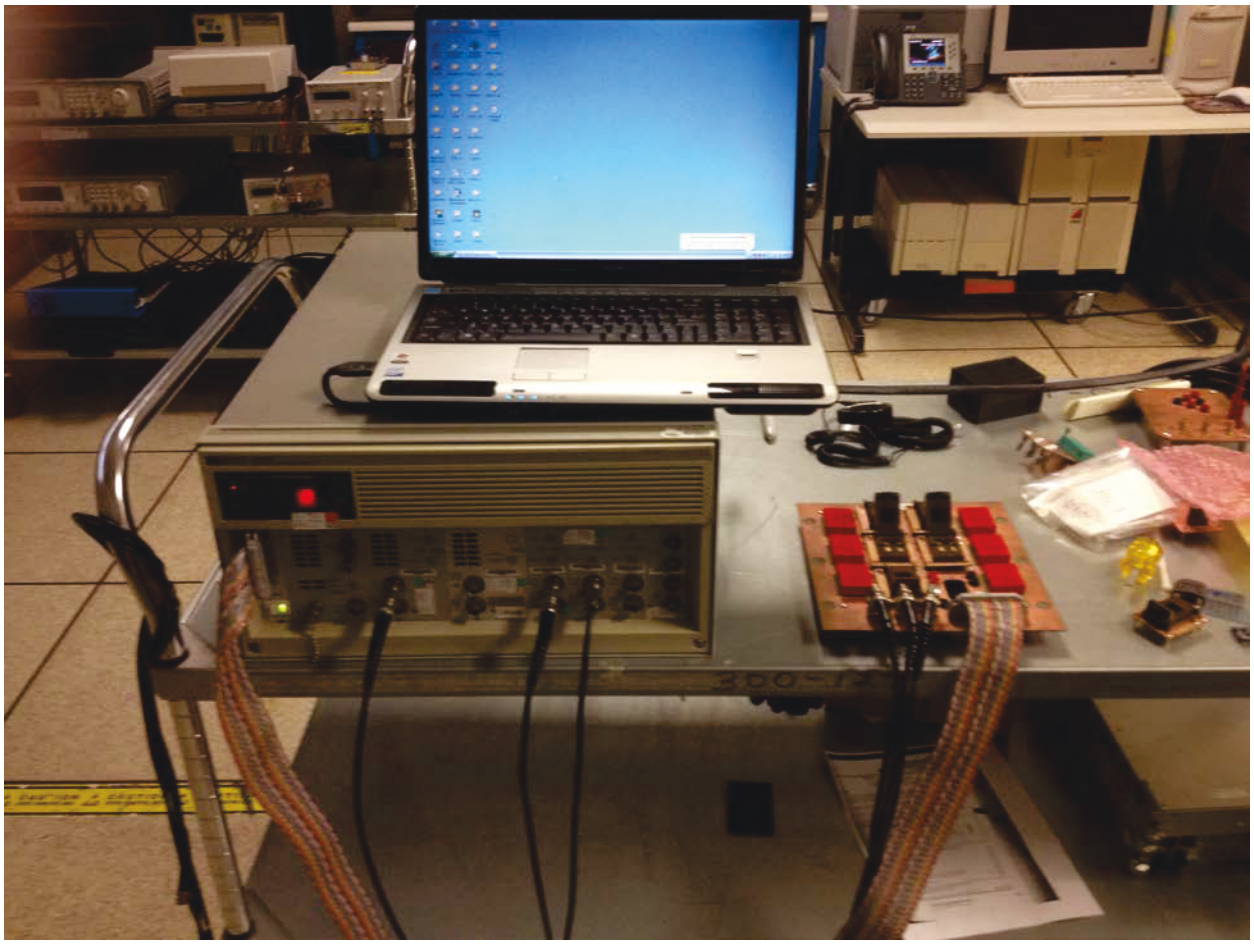

Figure 7.1-1. Setup used for SEE testing. Entire system is transported to heavy ion site

8.0 PROCEDURE

General test procedure shall adhere to the "The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs" [JPL Publication 08-10 2/08]. Parts shall be serialized (if not already done), with controls marked prominently to distinguish them from test samples. Exposures shall be performed at ambient laboratory temperature.

9.0 RESULTS

All of the tests proceeded without anomaly. No latent damage or small breaks were seen, but a majority of the device failures during the post irradiation stress tests, and not during beam irradiation.

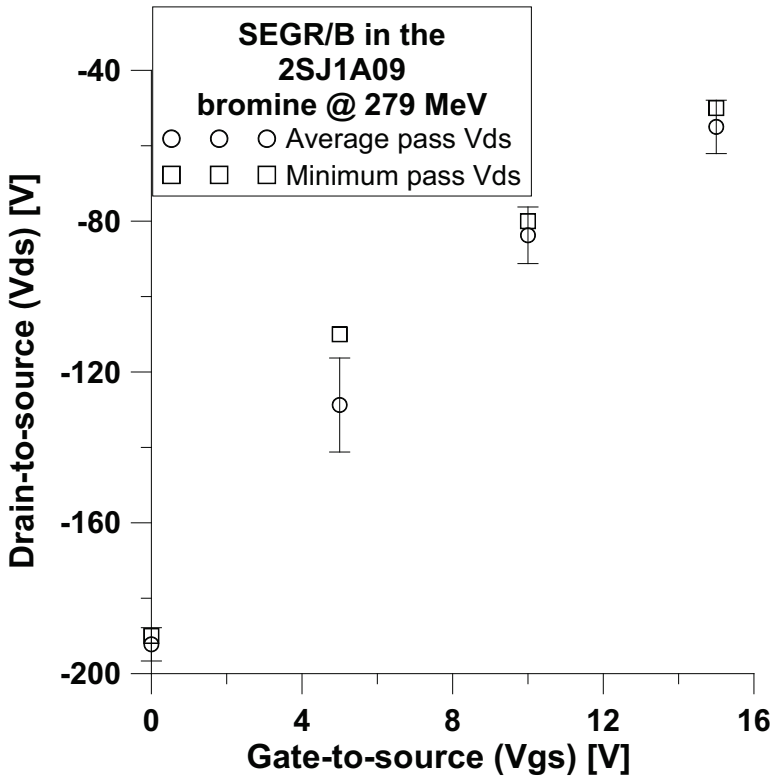

Figure 9.0-1. SEE test results of the 200 V Fuji p-channel with Br-279 at BNL. These data are comparable to results from similar ions at TAM (cf. Figure 9.0-2)

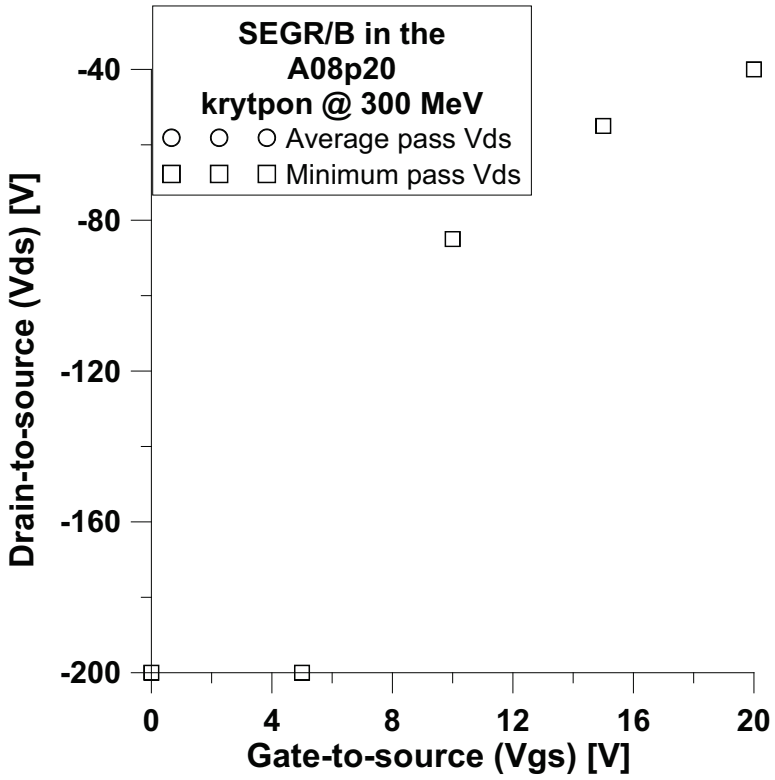

Figure 9.0-2. SEE test results of the 200 V Fuji p-channel with Kr-300 at TAM. These data are comparable to results from similar ions at BNL (cf. Figure 9.0-1). Note that at Vgs=-5 V, no SEE occurred and this effect is under investigation.

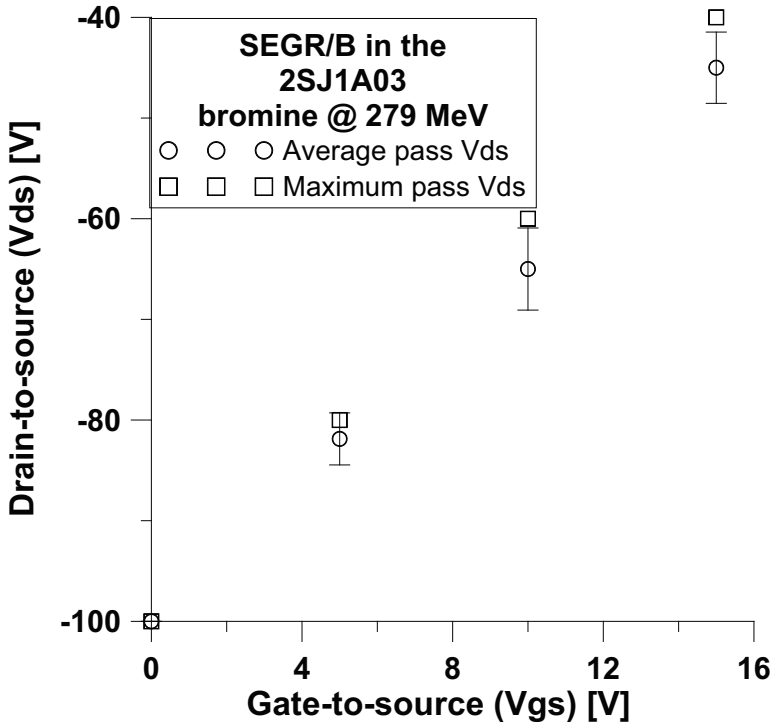

Figure 9.0-3. SEE test results of the 100 V Fuji p-channel with Br-279 at BNL. These data are comparable to results from similar ions at TAM (cf. Figure 9.0-4)

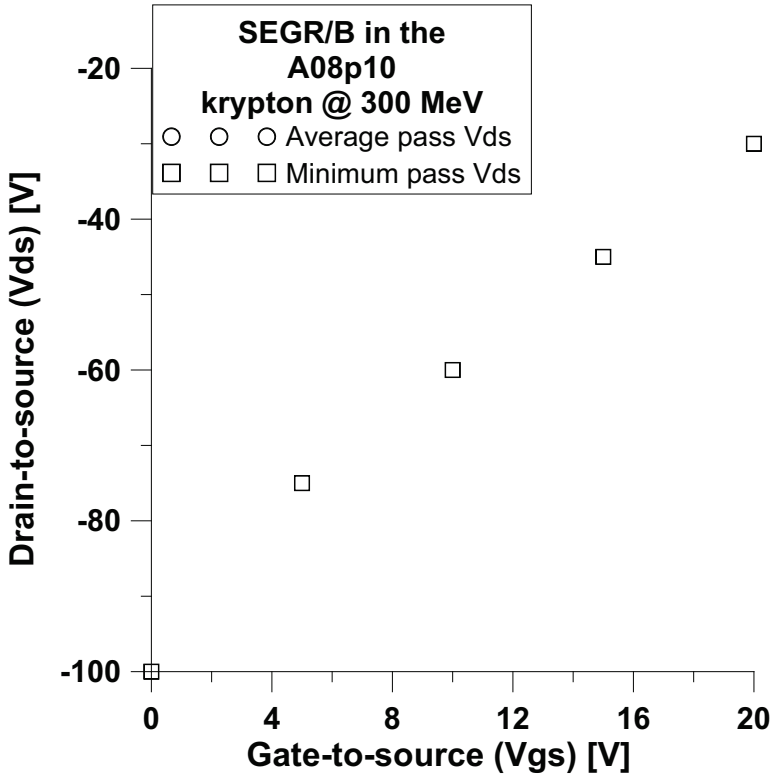

Figure 9.0-4. SEE test results of the 100 V Fuji p-channel with Kr-300 at TAM. These data are comparable to results from similar ions at BNL (cf. Figure 9.0-3).

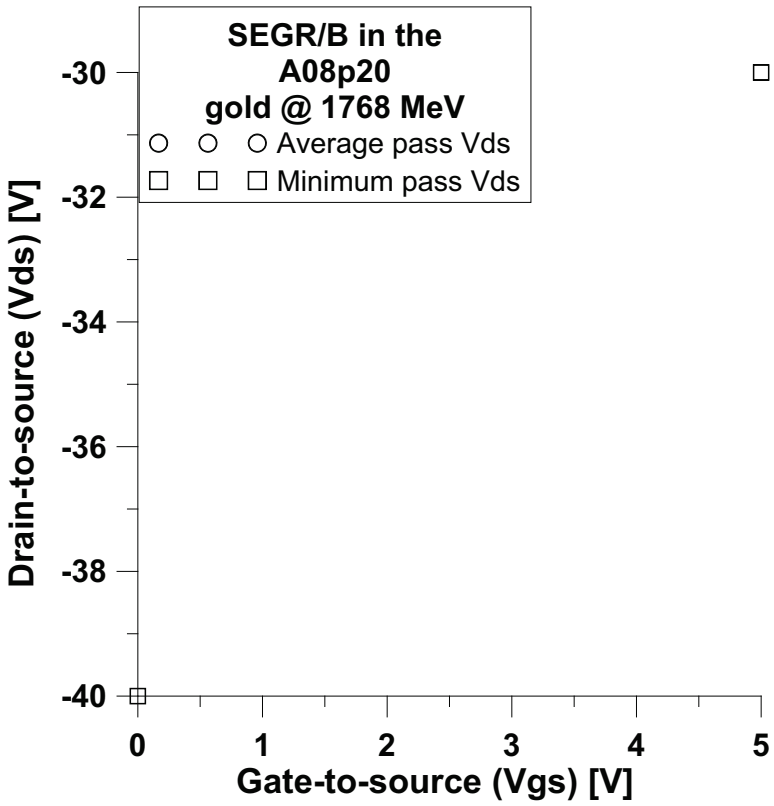

Figure 9.0-5. SEE test results of the 200 V Fuji p-channel with Au-1768 at BNL.

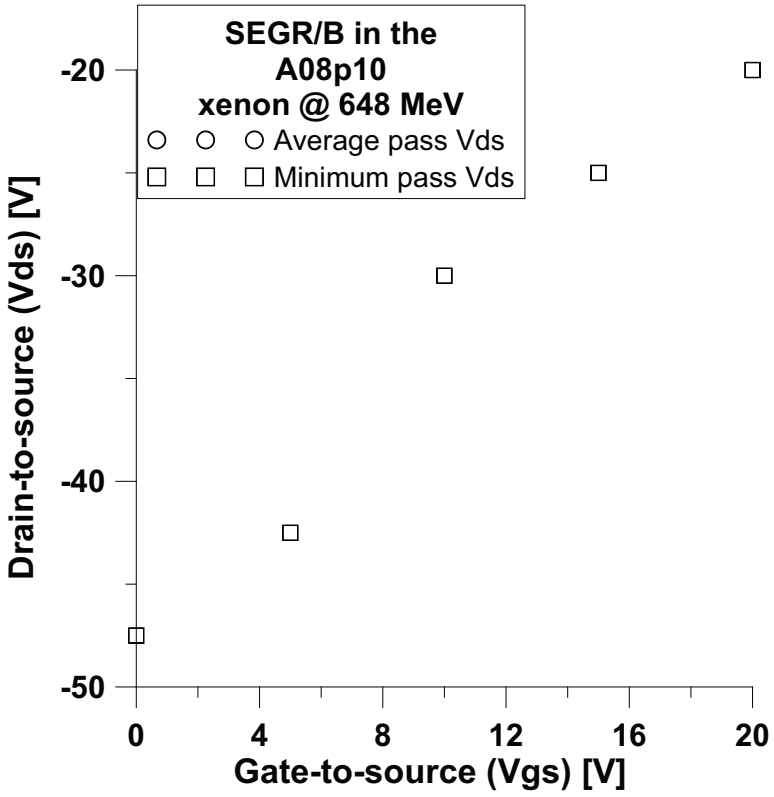

Figure 9.0-6. SEE test results of the 100 V Fuji p-channel with Xe-648 at TAM.

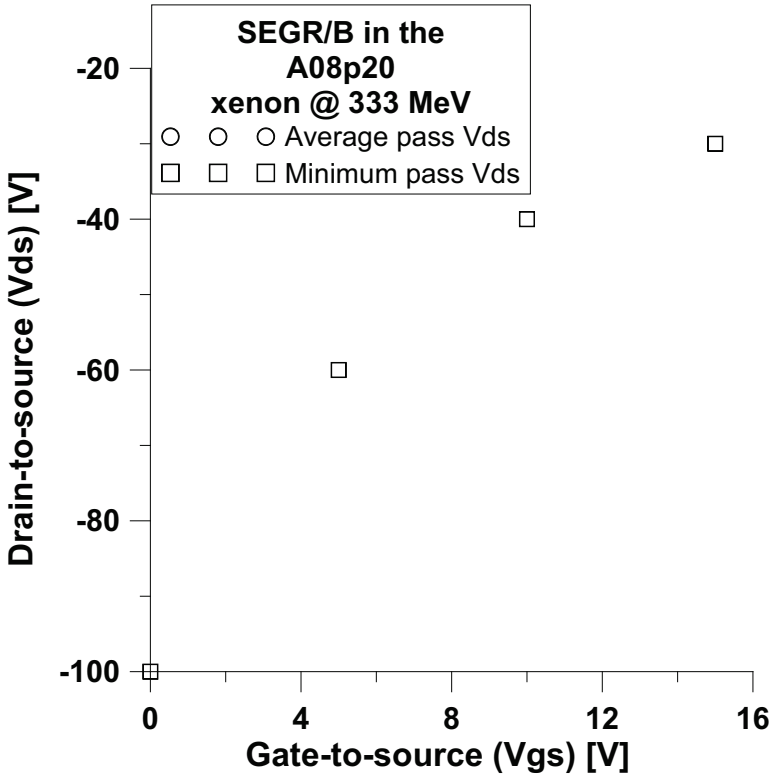

Figure 9.0-7. SEE test results of the 200 V Fuji p-channel with Xe-333 at TAM.

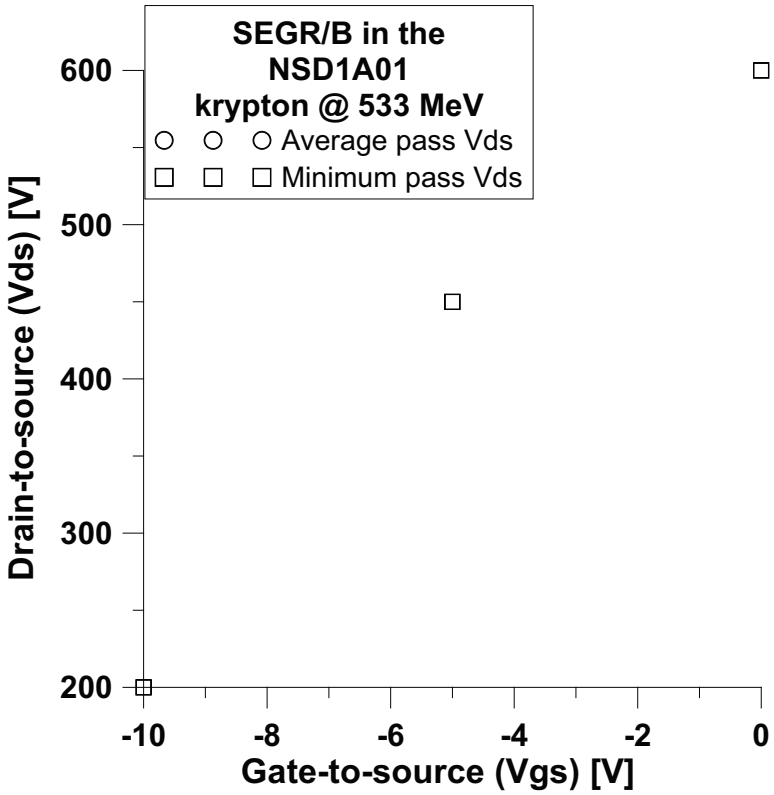

Figure 9.0-8. SEE test results of the 600 V Fuji n-channel with Kr-533 at TAM.

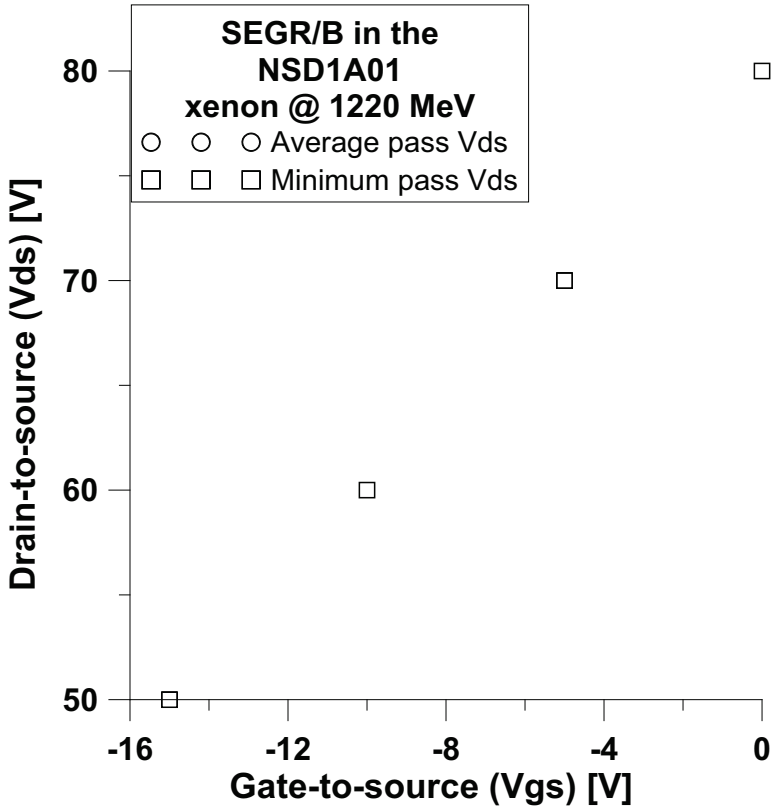

Figure 9.0-9. SEE test results of the 600 V Fuji n-channel with Xe-1220 at TAM.

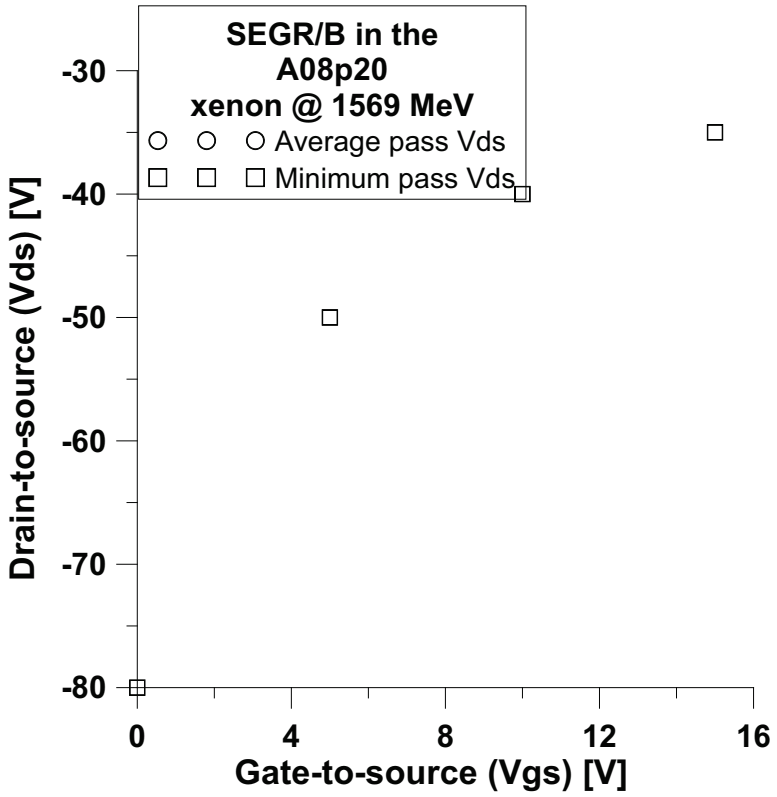

Figure 9.0-10. SEE test results of the 200 V Fuji p-channel with Xe-1569 at TAM.

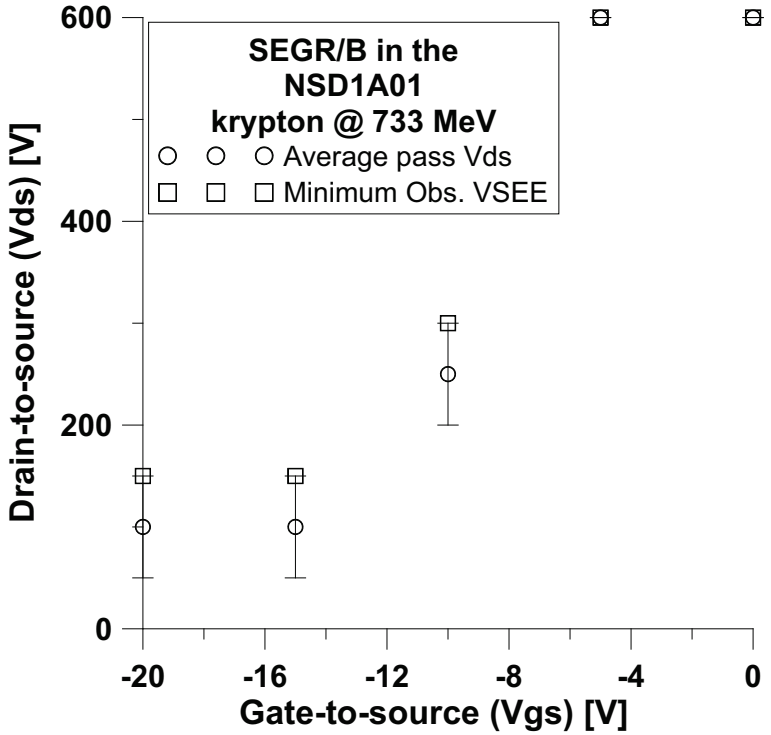

Figure 9.0-11. SEE test results of the 600 V Fuji n-channel with Kr-733 at TAM.

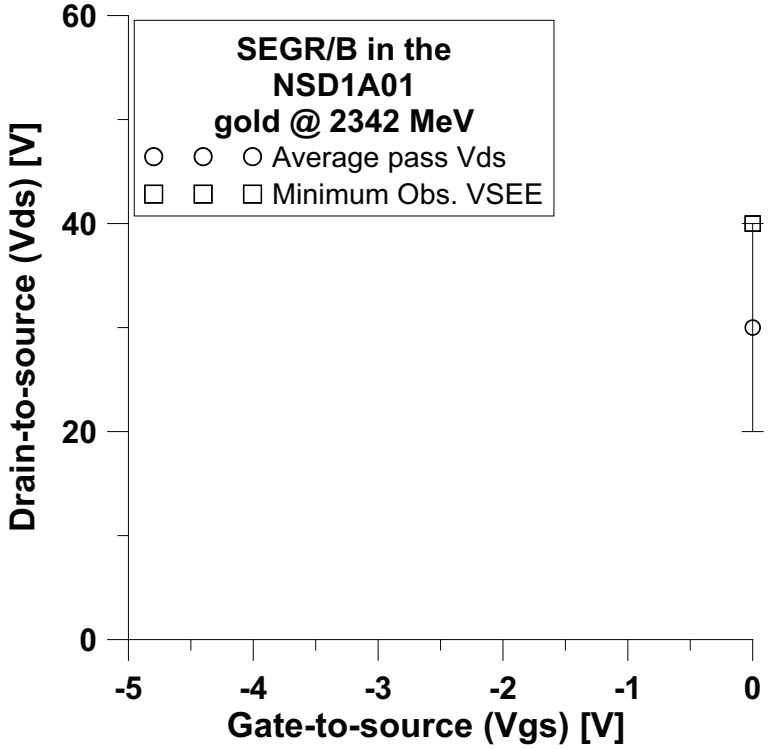

Figure 9.0-12. SEE test results of the 600 V Fuji n-channel with Au-2342 at TAM.

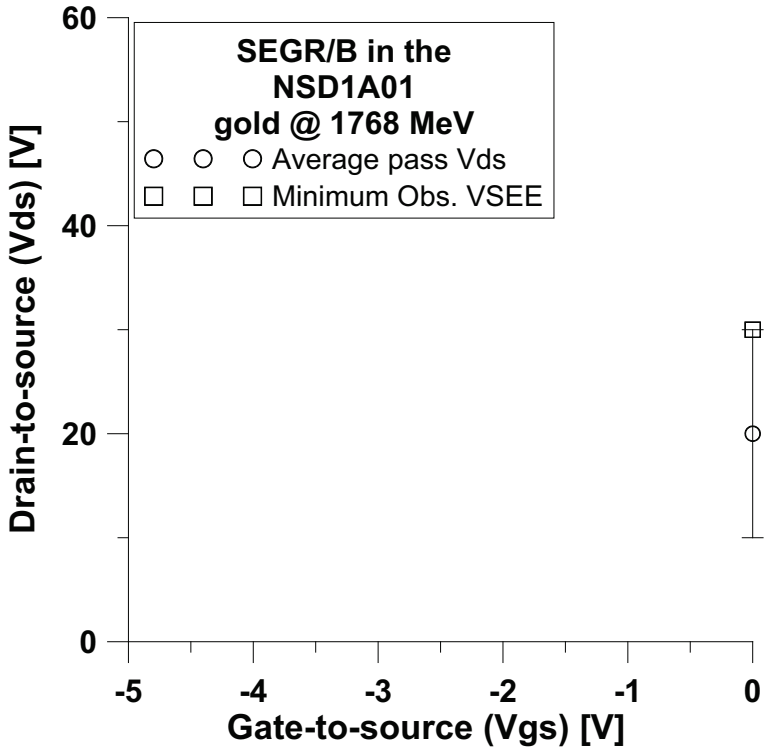

Figure 9.0-13. SEE test results of the 600 V Fuji n-channel with Au-1768 at TAM.

10.0 CONCLUSION AND RECOMMENDATION

These parts are comparable to similarly rated non-SE-hardened devices. However, the observations that the gate rupture occurred on the stress test as opposed to during the irradiation will require that testing of these devices employ the stress test for part assurance.

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